

December 8, 1892.

The LORD KELVIN, D.C.L., LL.D., President, followed by Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The President announced that he had appointed as Vice-Presidents—

The Treasurer.
Mr. W. T. Blanford.
Prof. G. C. Foster.
Prof. Lockyer.

The following Papers were read :—

- I. "On the Photographic Spectra of some of the Brighter Stars." By J. NORMAN LOCKYER, F.R.S. Received November 3, 1892.

(Abstract.)

The present communication consists of a discussion of 443 photographs of the spectra of 171 stars, which have been obtained at Kensington and Westgate-on-Sea during the last two years.

The chief instrument employed in this work has been a 6-inch refracting telescope in conjunction with—at different times—objective prisms of $7\frac{1}{2}^{\circ}$ and 45° respectively.

By this method the time of exposure is short, and good definition, with large dispersion, is easily secured. The spectra thus obtained will bear enlargement up to thirty times without much sacrifice of definition.

The 30-inch reflector and slit-spectroscope at Westgate-on-Sea have also been used in the inquiry.

My object has not been so much to obtain photographs of the spectra of a large number of stars as to study in detail the spectra of comparatively few.

In the classifications of stars adopted by others from a consideration of the visual observations, only the broader differences in the spectra have been taken into account. Professor Pickering has more recently employed a provisional classification in connexion with the Henry Draper Memorial photographs of stellar spectra, but this chiefly relates to photographs taken with small dispersion. With

larger dispersion it becomes necessary to deal with the presence or absence of individual lines.

In the first instance, the various stars of which the spectra have been photographed at Kensington have been arranged in tables, without reference to any of the existing classifications, and taking into account the finer details. The basis on which the main tabular divisions of the spectra are founded is the amount of continuous absorption at the blue end. This distinction was not possible in the case of the eye observations.

The stars included in the first table are characterised by the absence of any remarkable continuous absorption at the blue end, and by the presence in their spectra of broad lines of hydrogen. These have been further classified in four sub-divisions, depending on the presence or absence of other lines.

In the stars of the second table there is a considerable amount of continuous absorption in the ultra-violet, and the spectra beyond K are very difficult to photograph as compared with the stars of the first table. In these stars the thickness of the hydrogen lines is about the same as in the solar spectrum. These also are arranged in two sub-divisions.

In all the stars included in the third table there is a very considerable amount of continuous absorption in the violet, extending to about G, and it is a matter of great difficulty to photograph these spectra, as most of the stars of this class are below the 3rd magnitude. The hydrogen lines are very thin. One sub-division includes the spectra which show flutings shading away towards the less refrangible end of the spectrum. The other comprises stars without flutings in their spectra. The brightest star in this table, α Orionis, is discussed in detail, the result tending to show that the temperature of the absorbing iron vapours is not much greater than that of the oxy-hydrogen flame.

The relations of the various sub-divisions to which reference has been made are then traced.

One important fact comes out very clearly, namely, that whether we take the varying thicknesses of the hydrogen lines or of the lines of other substances as the basis for the arrangement of the spectra, it is not possible to place all the stars in one line of temperature. Thus, there are stars in which the hydrogen lines are of the same average thickness, while the remaining lines are almost entirely different. These spectra cannot, therefore, be placed in juxtaposition, and it is necessary to arrange the stars in two series.

The next part of the paper consists of a discussion of the photographic results in relation to the meteoritic hypothesis. In the Bakerian Lecture for 1888, I brought together the various observations of the spectra of stars, comets, and nebulae, and the discussion

suggested the hypothesis that all celestial bodies are, or have been, swarms of meteorites, the difference between them being due to different stages of condensation. The new classification rendered necessary by this hypothesis differed from previous ones, inasmuch as the line of evolution followed, instead of locating the highest temperature at its commencement, as demanded by Laplace's hypothesis, placed it much later. Hence bodies of increasing temperature were demanded as well as bodies of decreasing temperature.

The question how far this condition is satisfied by the new facts revealed by the photographs is next discussed.

This involves the consideration of some points in connexion with the hypothesis to which brief reference alone has been made in previous communications. The phenomena to be expected on the hypothesis, and the actual facts, are given side by side below.

Nebulæ.

The bright lines seen in nebulæ should have three origins:—

(1.) The lines of those substances which occupy the interspaces between the meteorites. Chief among these, from laboratory experiments, we should expect hydrogen and gaseous compounds of carbon.

(2.) The most numerous collisions between the meteorites will be partial ones—mere grazes—sufficient only to produce comparatively slight rises of temperature.

(3.) There will, no doubt, be a small number of end-on collisions, producing very high temperatures, and there should be evidence of some high-temperature lines.

(1.) Lines at wave-lengths approximately very closely to the lines of hydrogen, and to some of the carbon flutings, appear in the spectra of nebulæ.

(2.) There is a fluting most probably due to magnesium at λ 500, and the longest flame lines of iron, calcium, and magnesium are seen.

(3.) The chromospheric line D_3 and another line at λ 4471 (which is always associated with D_3 in the chromosphere) have been recorded in the spectrum of the Orion Nebula.

Bright-Line Stars.

The lines seen in the spectra of bright-line stars should, in the main, resemble those which appear in nebulæ. They will differ, however, for two reasons given in the paper.

Professor Pickering has shown that the Draper Memorial photographs prove that bright-line stars are intimately connected with the planetary nebulæ, the lines in the spectra being almost identical.

Stars of Increasing Temperature.

Stage 1.—Immediately following the stage of condensation giving bright-line stars, the bright lines from the interspaces will be masked by corresponding dark ones, due to absorption of the same vapours surrounding the incandescent meteorites, and these lines will therefore vanish from the spectrum.

Owing to the interspaces being restricted, absorption phenomena will be in excess, and low-temperature metallic fluting absorption will first appear. The radiation spectrum of the interspaces will now consist chiefly of carbon.

Under these conditions the amount of continuous absorption at the blue end will be at a maximum.

Stage 2.—With further condensation, the radiation spectrum of the interspaces will gradually disappear, and dark lines replace the fluting absorption owing to increase of temperature, though this line absorption need not necessarily resemble that in the solar spectrum.

Stage 3.—(1.) The line absorption and the continuous spectrum at the blue end will diminish as the condensations are reduced in number, as only those vapours high up in the atmospheres surrounding the condensations will be competent to show absorption phenomena in consequence of the bright continuous spectrum of the still disturbed lower levels of those atmospheres.

The spectra of stars given in the third table answer these requirements. They show no bright lines under normal conditions.

The dark flutings in the visual spectrum agree very closely in position with the flutings seen in the flame spectra of manganese, lead, and iron. The evidence afforded by the photographs proves the actual presence of carbon radiation.

The photographs show a considerable amount of continuous absorption in the ultra-violet and violet.

The spectra consist of numerous dark metallic lines, but they do not exactly resemble the solar spectrum. α Tauri and γ Cygni are types of stars at this stage.

(1.) These conditions are satisfied by such stars as α Cygni, Rigel, Bellatrix, δ Orionis, and α Virginis. In these there is no continuous absorption at the blue end, the spectra consisting of simple line absorption.

(2.) Lines of iron and other substances will disappear at this stage, because the bright lines from the interspaces will counteract the lines in the same positions due to absorption of surrounding vapours.

(3.) The chances of violent collisions being now enormously increased, we should expect the absorption of very high-temperature vapours. The solar chromospheric lines may be taken as examples of lines produced at such temperatures.

(2.) In the spectrum of α Cygni, which represents the earliest example of this stage, there are a few of the longest lines of iron, but in other stars of this class the iron lines disappear.

(3.) The new lines which now appear include the chromospheric line at $\lambda 4471$, and possibly a few others.

The Hottest Stars.

The order of the absorbing layers should follow the original order of the extension of the vapours round the meteorites in the first condition of the swarm, and the lines seen bright in nebulae, whatever their origins may be, should therefore appear almost alone as dark lines.

In stars like α Andromedæ we have absorption lines agreeing in position with some of the bright lines which appear in nebulae.

Stars of Decreasing Temperature.

Stage 1.—Owing to the diminishing depth of the absorbing atmosphere, the hydrogen lines will, on the whole, get thinner, and new lines will appear. These new lines will not necessarily be identical with those observed in the spectra of stars of increasing temperature. In the latter there will be the perpetual explosions of the meteorites affecting the atmospheres, whereas in a cooling mass of vapour we get the absorption of the highest layers of vapours. The first lines

Taking Sirius as a type of stars in the first stage of decreasing temperature, it is found

to appear, however, will be the longest low-temperature lines of the various chemical elements.

Stage 2.—The hydrogen lines will continue to thin out, and the spectra will show many more of the high-temperature lines of different elements. These will differ from the lines seen in stars of increasing temperature owing to the different percentage composition of the absorbing layers, so far as the known lines are concerned.

Stage 3.—With the further thinning out of the hydrogen lines and reduction of temperature of the atmosphere, the absorption flutings of the compounds of carbon should come in.

that its spectrum shows many of the longest lines of iron.

The conditions at this stage of cooling are satisfied by such stars as β Arietis and α Persei. In the spectrum of these stars nearly all the solar lines are found, in addition to fairly broad lines of hydrogen.

There is undoubted evidence of the presence of carbon absorption in the solar spectrum and the spectrum of Arcturus, the only star which has yet been investigated with special reference to this point.

The photographs, then, give us the same results as the one formerly obtained from the eye observations.

Comparison is then made between the groups in the classification first suggested by the eye observations, and the various sub-divisions in which the photographs have been arranged.

II. "On the Velocity of Crookes' Cathode Stream." By LORD KELVIN, P.R.S. Received December 3, 1892.

In connection with his splendid discovery of the cathode stream (stream from the cathode in exhausted glass vessels subjected to electric force), Crookes found that when the whole of the stream, or a large part of the whole, is so directed as to fall on 2 or 3 sq. cm. of the containing vessel, this part of the glass becomes rapidly heated up to many degrees, as much as 200° or 300° sometimes, above the temperature of the surroundings.

Let v be the velocity, in centimetres per second, of the cathode stream, and ρ the quantity of matter of all the molecules in 1 c.c. of it. Supposing what Crookes' experiments seem to prove to be not far from the truth, that their impact on the glass is like that of inelastic bodies, and that it spends all their translational energy in heating the glass. The energy thus spent, per square centimetre